

DESIGN, ANALYSIS AND FABRICATE SMALL CROSS FLOW
TURBINE FOR SUNGAI PAHANG

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ABSTRACT

This thesis is about doing analysis and investigations on river flow rate in Malaysian River which focusing at Sungai Pahang, which is form the investigation the small cross flow are design by consider the data and the characteristic that are collected. Through this analysis and investigation could obtain the potential of running a Water Turbine System (WTS). Demand for electricity around the world increase day by day, and plant that are used nowadays many of that are not renewable energy such as coal power plant, fossil-fuel derived electricity, where the source and supply of this raw material source are decrease day by day and the price are increase, because of this global crisis water turbine system are come out. This innovation are come out to overcome this crisis due to the hydropower that are known as renewable power energy. This project are dedicated to people that leave deep inland can reach and used a electricity especially for this project are dedicated and special for Sungai Pahang river. The main problem statement is on location limitation to obtain peak flow rate of river to running water turbine systems which is depending on depth and width of the river and also from the velocity of sectional area of river. Other than that, choosing most suitable water turbine system is also one of main criteria to be taken in this research. Water Turbine are one of clean renewable energy sources which holding high percentage of energy resource provider among renewable energy. This thesis will carry on with modeling a WTS that can be recommended to construct in Sungai Pahang. The analysis on flow rate of Pahang River are done by calculating potential Power (Watt) that could produced based on volume flow rate data that obtain from Department of Irrigation and Drainage of Malaysia. Since water turbine could provide electricity power without affecting pollution to the environment. Water turbines systems also are cheapest resource to be obtain. Final modeling of water turbine system is completed by Computer Aided Design, CAD software and will be analys bu ising Computetional Fluid Dynamic, CFD software.

ABSTRAK

Tesis ini adalah menajalan analisis dan penyiasatan ke atas kadar aliran sungai di Malaysia, yang mana memberikan tumpuan khusus pada Sungai Pahang, dimana hasil penyiasatan akan di gunakan dalam mereka bentuk turbine berskala kecil yang sesuai berpandukan maklumat dan ciri-ciri Sungai Pahang. Melalui analisis dan penyiasatan ini, membolehkan perolehan maklumat mengenai potensi penggunaan Sistem Turbin Air (WTS). Sedia maklum permintaan untuk tenaga elektrik di seluruh dunia hari demi hari, dan loji yang digunakan sekarang adalah dari jenis tenaga tidak boleh diperbaharui seperti loji janakuasa arang batu dan bahan bakar fosil hi, di mana sumber dan bekalan sumber bahan mentahnya adalah semakin berkurangan hari demi hari dan ini menyebabkan harga peningkatan harganya, oleh sistem air turbin diperkenalkan bagi menangani krisis global yang melular ini. Inovasi ini adalah untuk mengatasi krisis ini kerana kuasa hidro adalah tenaga kuasa yang boleh diperbaharui. Projek ini didedikasikan untuk komuniti yang tinggal di pedalaman, melalui hasil projek ini capaian dalam penggunaan elektrik dapat dikurangkkn jurangnya, dan projek ini adalah khusus bagi Sungai Pahang. Masalah utama adalah had lokasi untuk mendapatkan kadar aliran tertinggi sungai untuk menjalankan sistem ini dimana ianya turut berkait rapat dengan kelebaran sungai dan kedalaman sungai itu sendiri. Selain daripada itu, memilih sistem turbin yang paling sesuai juga merupakan salah satu kriteria utama yang perlu diambil dalam kajian ini. Sistem turbin air adalah salah satu sumber tenaga yang bersih boleh diperbaharui yang mana merupakan sistem utama di dalam pembekalan sumber bersih tenaga elektrik. Tesis ini dijalankn dengan memodelkan Sistem Turbin Air (WTS) untuk disyorkan untuk digunakan di Sungai Pahang. Analisis ke atas kadar aliran Sungai Pahang adalah dilakukan dengan mengira potensi Kuasa (Watt) yang boleh dihasilkan berdasarkan data kadar aliran isipadu yang diperolehi dari Jabatan Pengairan dan Saliran Malaysia. Dengan penggunaan sistem turbin air, ianya dapat menghasilkan kuasa elektrik tanpa menjejaskan alam sekitar. Sistem turbin air juga adalah sumber yang paling murah. Pemodelan akhir sistem turbin ini adalah menggunakan perisian Computer Aided Design, CAD dan akan analisis aliran adalah dengan menggunakan perisian Computetional Fluid Dynamic, CFD.

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LIST OF ABBREVIATIONS

POM	Polyoxymethylene
WTS	Water Turbine System
DC	Direct Current
FRP	Fiberglass Reinforced Plastic
CAD	Computer Aided Design
CFD	Computational Fluid Dynamics
MIG	Metal Inert Gas
ARC	Shielded Metal Arc Welding
L	Length
W	Width
T	Temperature
K	Kelvin
Re	Reynold Number
kg	kilogram
Pa	Pascal
MPa	Megapascal
2-D	Two Dimension
V	Velocity
V_1	Velocity inlet
V_2	Velocity outlet
SI units	System International units
N	Newton
mm	Millimeter

	Density
UNESCO	United Nations Educational, Scientific and Cultural Organization
	Extractable power of a water jet
Q	Volumetric flow rate
H	Head of the water
	Acceleration due to gravity
A	Cross sectional area
A_1	Cross sectional area inlet
A_2	Cross sectional area outlet
P_s	Shaft power
P_e	Electrical power
F	Tangential force
	Angular speed
	dynamic viscosity
	Pitch radius
	Mechanical efficiency
U	Voltage across the load
I	load current
	Length of nozzle
D_h	hydraulic diameter

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Nowadays, electricity is one of an important thing in daily life, the demand increase day by day due to the increasing the capacity of human being and also of the transportation demand, where such as electric motorcycle, car and train. Hydro power in conservation of water flow energy to another form of energy, electricity which is common power used in nowadays modern era world.

The electricity generate by the rotating of turbine blade cause of river flow into electrical current by means of an electrical generator where the power are stored in the cell. Water turbine is used in big scale like dam, where involve such an edifice that are changed the landscape of nature which is not eco-friendly. For this purpose small individual turbines are promoted to Sungai Pahang which is beneficial to all that are involved and attach to this river. Hydro power energy also plentiful, renewable, reliable source of energy, clean, easy to handle, easy to do maintenances and reduces toxic atmospheric and greenhouse gas emission if used widely where can replace fossil-fuel derived electricity

A small cross water flow turbine is a machine that is converts the kinetic energy to another form of energy, where in form of mechanical energy. This mechanical energy then converts to electricity energy which is called hydro generator, or hydro energy converter.

This turbines can defined in two types, depend on the axis of the turbine and there are Vertical and Horizontal axis cross water flow turbine.

This small scale cross flow turbine only can produce a small amount of energy, if compared to conventional type. But for this type it more eco-friendly which is no need such a massive construction that are known will affect the eco system of the area that are involve in the construction and also need such a long period of time to set it up. This small cross flow turbine may produce at kilowatt, kW, or lower electricity power. But for this project the aim is for the small community in inland and also for the bridge light purpose. Within affect a very minimum effect to eco system.

1.2 PROBLEM STATEMENT

For this century a renewable energy not just an optional but a need, because of a source of the conventional energy decrease day by day and the global price raised every day. The world stock and need are greater than supply and also increasing of the mankind day by day, (UNESCO). By using a small cross flow turbine is and a perfect fit because of fulfill all the criteria such as clean, green and renewable. This project target area is along Sungai Pahang, known as backbone off peninsular Malaysia.

This project is also hopefully be one and a popular alternative in Malaysia due to generate an electricity, especially due to the target area for inland community and also facilities such as bridge that are built to across the river that are located far inland along Sungai Pahang. This project that are cheaper and easy to conduct and maintenance where these criteria also include to the green way for the renewable energy.

This project are choose because of more weather friendly, compared to other alternative such as solar panel, this is because Pahang are located in the East of Malaysia that has a rainy season, for solar panel, during rainy season the sunlight are so minimum because of the long period raining time, and solar panel just can be at maximum output at

day, differ for small water turbine it can keep produce an electricity a day and night. Compared to the wind turbine for target area such as a long Sungai Pahang, the open space are limited and it full of tree where it is obstacle for the maximum wind flow.

1.3 PROJECT OBJECTIVES

The objectives of this project is:

- i. To fabricate the prototype cross flow water turbine system.
- ii. Increase flow rate of river flow

1.4 SCOPES OF PROJECT

The scopes of this project are:

- i. Modeling and simulating the prototype suitable software.
- ii. Validate the design by performing test of flow rate water speed by using CFD software.

1.5 PROJECT METHODOLOGY

This methodology must be detail and closely dovetailing the flow chart of the overall project. After the objective has been set, it comes the way to setup the experiment from the early to the end of this project. The execution of this project has to follow the flow that is already set, to ensure that the project will be done smoothly and without any discrepancies. The overall of the project is shown in Figure 1.1

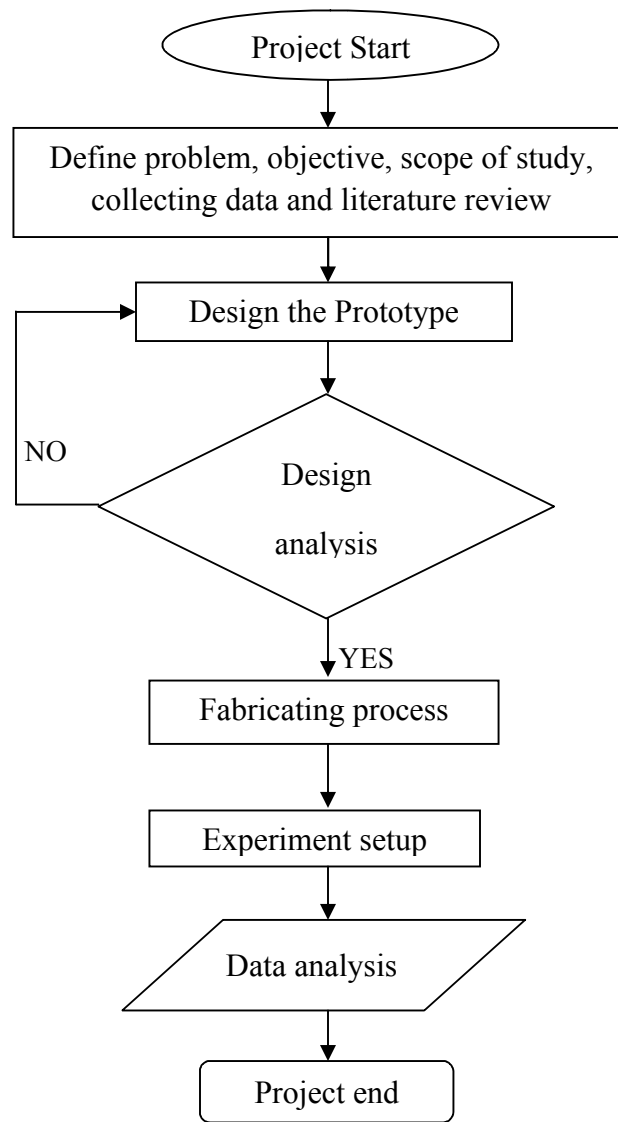


Figure 1.1: Methodology of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In 1892, John B. McCormick invented a water wheel, before his design and a mixed-flow style turbine in 1899. Water turbine basically made of steel that are attach to the chassis that are hold the turbine in order to generate electricity. The reason John B. McCormick to develop of this invention is to “Going Green” before the term even existed, dedicating his life to inventing more efficient ways to create power for industry, he started with basic improvements to the water wheel, the simplest type of water turbine, and one of the oldest forms of power and irrigation, dating back to the ancient Egyptians. The water wheel utilizes falling or flowing water to turn a large wheel centered on a shaft. This shaft then spins and, in McCormick’s time, would power a set of gears in a mill. The water is caught by either blades or buckets and nothing but the natural force (potential energy) of water is used to create power.

John McCormick the physics of the water wheel took into consideration and created a version that was more suited for industry. In his design, the water wheel is enclosed in a metal casing that water is flown through. The blades of the water wheel have small flaps that are angled from the perpendicular that catch the water as it flows, and turn the wheel. The overall shape is similar to that of a bell as the diameter of the metal casing widens from top to bottom. The water enters through the thin end and the water wheel is in the thick end. The water flows from the thin end, to the thick end, turning the wheel in doing so. Design patented flow water turbine detail is shown in the Figure 2.1.

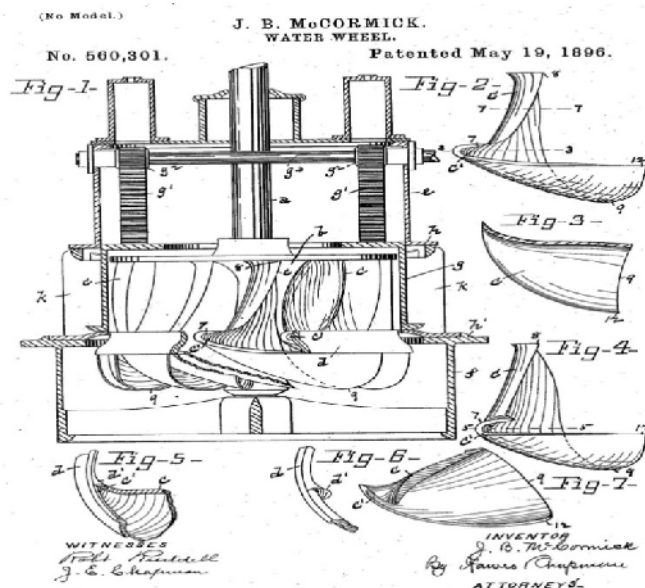


Figure 2.1: Patented flow water turbine

Source: John B. McCormick, 1896

The turbine style water wheel that McCormick invented in 1892 was just one of a few improvements he made to the water wheel before designing the mixed-flow style turbine in 1899. A turbine is a machine that uses the kinetic (moving) energy from a flowing gas or liquid such as steam or water to turn a series of blades or fans. This process converts kinetic energy to mechanical energy. In a power plant, a turbine is used to turn a conducting wire in a generator to produce power. A turbine is based on a principle made famous by physicist Isaac Newton. His third law of motion states that for every action there is an equal and opposite reaction. In a turbine, the action is the flowing fluid and the reaction is the turning blades.

The efficiency of an axial turbine is around 70%-75%. This is because there is space between the rotor blades for fluid to pass through. The only way for all of the air blowing at a windmill to be captured was if the windmill were a complete, solid circle. At the same time, if the windmill were a complete, solid circle there would be no way for the turbine to catch the air in a useful way, and because of this it is impossible to have an axial turbine with 100% efficiency.

2.2 THEORY OF WATER TURBINE

The total extractable power of a water jet is shown in Eq.(2.1).

$$P = \rho Q g h \quad (2.1)$$

where:

Q is the volumetric flow rate (m^3/s).

h is the available head of the water source (kg/m^3)

g is the acceleration due to gravity (9.81 m/s^2),

ρ is the density of the water (kg/m^3).

The speed of the water jet v is found from the flow rate and the cross section area A of a circular nozzle with diameter D , the detail are shown in Eq.(2.2).

$$v = Q / A = Q / (\pi D^2 / 4) \quad (2.2)$$

where:

A is cross section area of nozzle (m^2)

D is the diameter of the nozzle (m)

The mechanical power P_s available at the turbine shaft can be determined by measuring the torque t on the shaft at a corresponding angular speed ω . The torque is found by measuring the tangential force F on a brake lever with moment arm length l , while simultaneously measuring the rotational speed r of the shaft, as depicted in Figure 2.1. The shaft power is then P_s is shown details in Eq.(2.3).

$$= \quad = 2 \quad (2.3)$$

where:

is torque (N)

is arm length (m)

is the tangential force (N)

The angular speed is the tangential speed of the turbine divided by the pitch radius L of the Pelton wheel, the detail calculation is shown in Eq.(2.4).

$$= \quad / \quad (2.4)$$

where:

L is pitch radius of the Pelton wheel (m)

is the tangential speed of the turbine (m/s)

The mechanical efficiency, of the turbine describes how effectively the available kinetic energy of the water jet is transformed into turbine motion and from Eq.(2.1) and Eq.(2.3) is shown details in Eq.(2.5).

$$= \quad / \quad = 2 \quad / \quad h \quad (2.5)$$

Cup and jet design are important parameters and it can be shown in Eq.(2.5), that maximum theoretical mechanical efficiency is achieved when the tangential speed of the turbine is roughly one-half the speed of the water coming from the jet or, the Eq.(2.6), is shown the detail.

$$/ \quad \approx 0.5. \quad (2.6)$$

where:

is the tangential speed of the turbine (m/s)

is the speed of the water (m/s)

When the turbine shaft is coupled to an electric generator which supplies electricity to a variable resistive load R , the electrical power Pe of the load is shown in Eq.(2.7).

$$Pe = IU \quad (2.7)$$

where:

I is the is the load current (amps)

U is the voltage across the load (V)

The rotating shaft will produce the torque at the shaft with length l of the shaft rotating rod, the detail are shown in the Figure 2.2 below.

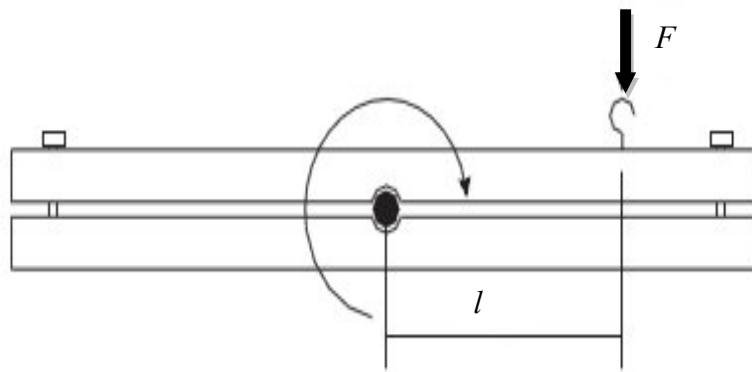


Figure 2.2: The measurement of the torque on the turbine shaft is performed using a brake lever with a moment arm length l .

Source: Renewable Energy 33 (2008)

The lever consists of two wooden splints which are clamped around the shaft by use of two screws. The tangential force F is measured directly using a spring scale. In which I is the load current and U the voltage across the load? The electrical efficiency of the generator and the overall efficiency is shown by Eq.(2.8) and of hydroelectric generation are then shown in Eq.(2.9).

$$\eta = \frac{P_{\text{out}}}{P_{\text{in}}} = \frac{IU}{2\pi l F} \quad (2.8)$$

$$\eta = \frac{P_{\text{out}}}{P_{\text{in}}} = \frac{IU}{\dot{m} h} \quad (2.9)$$

The Pelton turbine consists of a cylindrical hub onto which 12 vanes have been fastened using screws and right angle aluminum brackets. The hub and vanes were made of polyoxymethylene, POM, plastic for easy machine ability. The pitch radius of the turbine, which is the distance from the center of the shaft to the center of the impact point of the water jet, should be roughly 10 times the diameter of the jet so that adjacent vanes do not interfere with the water flow. The twin cups on each vane were shaped by milling two parallel 26 mm hemispherical grooves using an 8 mm ball-end cutter. The tips and back sides of the vanes were shaped by free-hand grinding with a belt sander. The shape and size of the hub and cups were selected according to available tools and materials.

Other geometries or manufacturing methods would, most certainly, work equally well. The turbine shaft is supported directly by the transparent acrylic turbine housing which allows the action of the water to be easily observed. No attempt was made to balance the finished turbine. The device is shown in Figure 2.3 with the upper section of the housing removed for better viewing. A hose-coupling connector from a garden supply store is used as a water nozzle. It is located on the lower corner of the housing, and has been attached using thick flexible rubber gaskets which allow the impact point of the jet to be adjusted so that it strikes the dividing ridge between cups on the lower side of the turbine. The nozzle diameter is about 6 mm and the pitch radius of the turbine is about 60 mm.



Figure 2.3: Details of the Pelton wheel showing the 12 vanes evenly spaced around the central hub.

Source: Renewable Energy 33 (2008)

The turbine shaft is fitted with a pulley wheel (foreground) which drives the Direct Current, DC, generator (not shown) using a rubber belt. The nozzle is shown in the lower-right corner. The upper part of the housing was removed for the photograph.

Outside the housing, the back of the nozzle is fitted with a T-connection which is used for the incoming water source and for the measurement of pressure, respectively. A pressure gauge can be fitted directly to the back of the nozzle or a connection to a mercury manometer can be made. In the system under discussion both methods have been used to determine the pressure but the manometer method appears more instructive to students.

Water is supplied to the nozzle by an electric pump and flexible tubing. After striking the vanes, water exits the turbine housing through a hole at the base and flows back to an enclosure in which the intake of the pump is located. The volume flow rate of water is measured and controlled using a magnetic volume flowmeter¹ and hand-operated valve. A more simple low-cost method, however, is to use a graduated liquid measure and a stop watch to measure the volume flow.

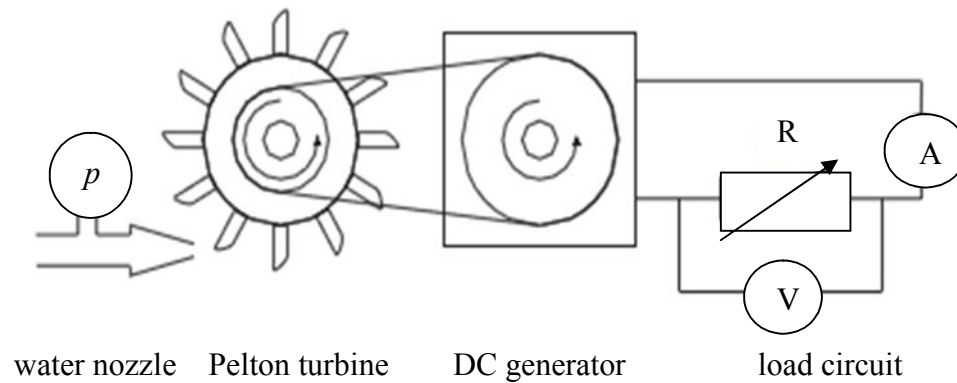


Figure 2.4: A schematic showing the experimental setup for the Pelton wheel water turbine experiment.

Source: Renewable Energy 33 (2008)

One end of the turbine shaft extends through the wall of the housing and is fitted with a pulley wheel, which drives a small Direct Current, DC, electric generator by use of a rubber belt. The generator itself is a salvaged motor from a Direct Current, DC, and cooling fan. In order to determine the rotational speed of the turbine, a frequency-adjustable stroboscopic light is used to illuminate the pulley wheel. While observing reference marks on the spinning pulley wheel, the strobe frequency is adjusted until a particular mark appears to be stationary.

When this is observed, the frequency of the strobe and the speed of rotation of the wheel are equal, assuming the experimenter has eliminated the possibilities of corresponding harmonic frequencies.

A brake lever is used to determine the torque on the turbine shaft. The lever is made from two wooden splints, which when fitted together and tightened with two screws; apply a frictional force on the turbine shaft. While the shaft is spinning, the force acting at right angles on the lever can be measured directly with a spring scale calibrated in Newton. For

the turbine under discussion, measured forces have been in the range of 0.1–1.5N with a moment arm length of some 70 mm.

The load circuit of the DC generator consists of an adjustable 0-100 k Ω , decade resistor. Load current and Voltage have been measured using digital multi-meters. The experimental setup is shown in Figure 2.4.

Students have conducted experiments with the Pelton turbine using three different water volume flow rates, referred to as Q_1 , Q_2 and Q_3 . The water pressure p at the nozzle is measured for each Q value with the turbine shaft rotating freely. In Eq.(2.10) is shown the equation to calculate, if a mercury manometer is used, the power P_w from Eq.(2.1) is,

$$P_w = pQ = \frac{\rho g h Q}{2} \quad (2.10)$$

where:

Q , Q_1 , Q_2 , Q_3 is the volumetric flow rate (m^3/s).

g is the acceleration due to gravity (9.81 m/s^2),

ρ is the density of mercury ($13\,550 \text{ kg/m}^3$)

h is height difference between the two mercury columns (m)

The relationship between the tangential force on the shaft and the speed of rotation is then determined using the brake lever for each Q value. An empirical expression for the force as a function of rotational speed is fitted to this data using appropriate software. This relationship is generally found to be of a linear nature in the range of variables described.

With the drive belt connected to the Direct Current, DC, generator and the brake lever removed from the turbine shaft, the current and voltage of the resistive load are measured, while simultaneously measuring the rotational speed of the turbine. This is repeated for several values of load resistance. The measurement yields the electrical power produced by the generator as a function of rotational speed. The expressions found for